Chapter-5

Regulatory Structures

Intake:

Structure at the entrance of pipe, canal or tunnel through which water is conveyed

Types of intake:

1) Based on Layout
    i. Side Intake
        - Intake at side or bank of the river
        - Usually adopted when power house is away from dam.
    ii. Frontal Intake:
        - Suitable when majority of sediment carried by the river is bed load.
        - Suitable for relatively clean water.
        - Suitable for storage or peaking type plants.

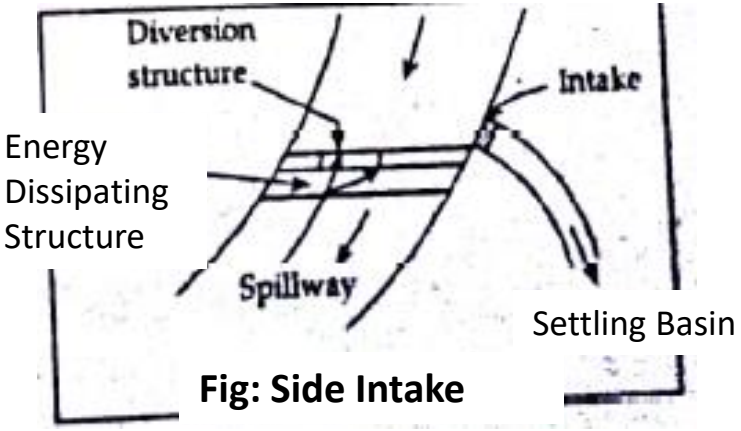


Fig: Side Intake

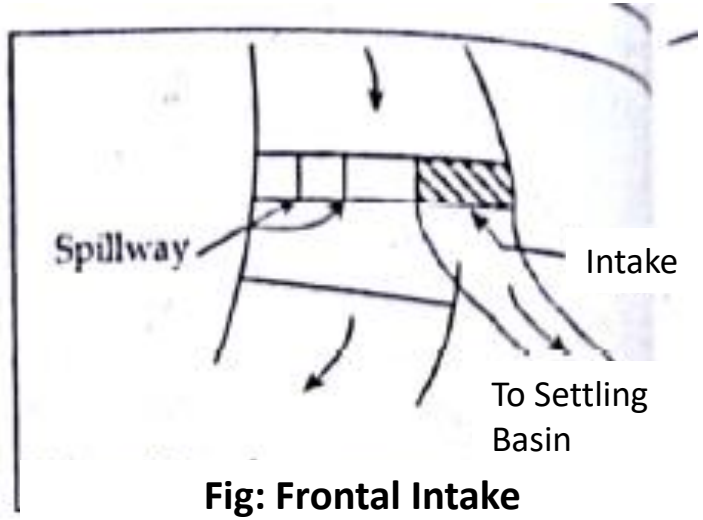
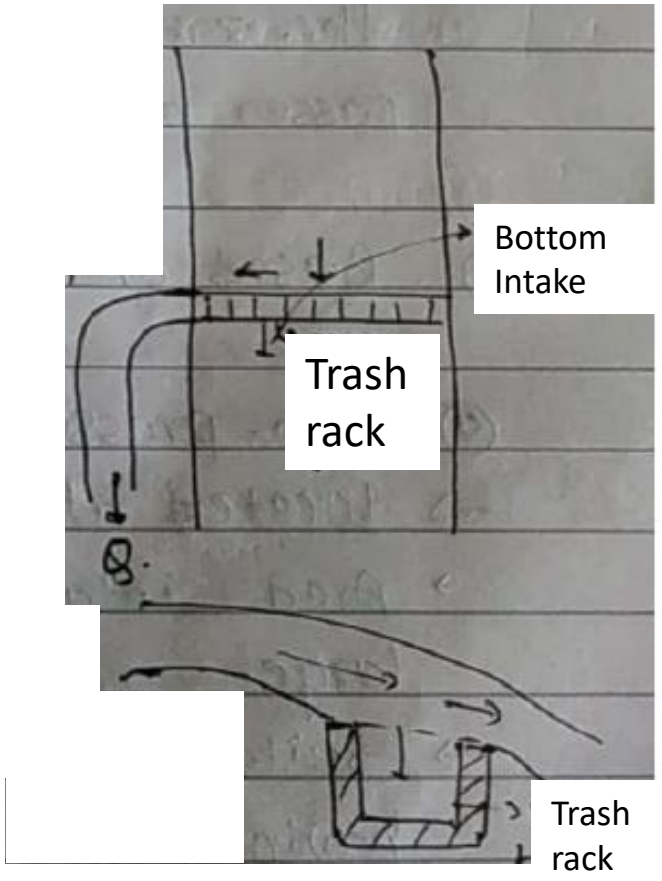


Fig: Frontal Intake

iii) Bottom Intake/ Drop Intake / Tyrolean Intake

- Grill like opening that captures water from the bed of the river and drops it directly to the head race.

- Suitable for following conditions:
  - When there is no appreciable movement of sediment along the river.
  - Minimum Bed load
  - For steep rivers with rocks in river beds



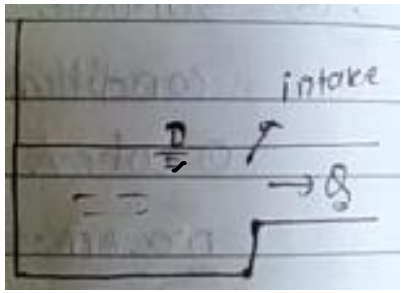
Selection of Type of Intake:

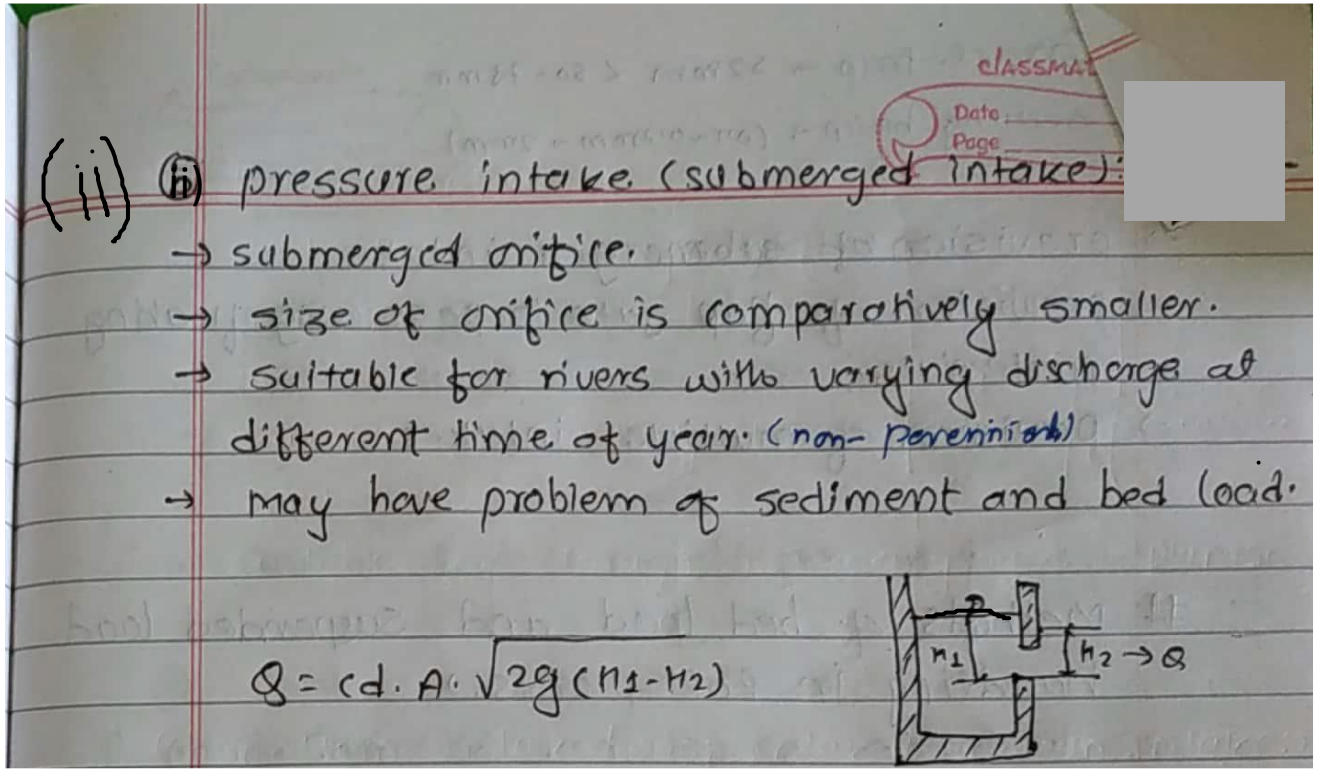
1. Nature of River
   - Side intake may be used in all types of river ranging from mild sloping to steep rivers
   - Drop intakes are limited to small mountainous / hilly river with rocky river beds.
   - Frontal intakes: River is wide and carries relatively clear water
2. Sediment, trash and debris Content:
   - Side Intake: suitable for Nepali river which carry large amount of sediment, trash and debris during monsoon
   - Frontal Intake: Suitable if the majority of sediment is bed load
   - Drop Intakes: should be avoided in rivers with high sediment content
3. Nature of Hydropower Plant
   - Frontal -> Low head plants, Drop -> small hydropower plants on small streams, Side -> Any type of ROR

2. Based on Hydraulic regime:

i) Non Pressure intake (surface intake)

- Located at surface
- Area of intake is comparatively large.
- Suitable for perennial rivers
- May have problem of floating materials




(ii) (b) pressure intake (submerged intake):
→ submerged orifice.
→ size of orifice is comparatively smaller.
→ suitable for rivers with varying discharge at different time of year. (non-perennial)
→ may have problem of sediment and bed load.
$Q = c_d \cdot A \cdot \sqrt{2g(H_1 - H_2)}$
H_1
$H_2 \rightarrow Q$

Location of intake

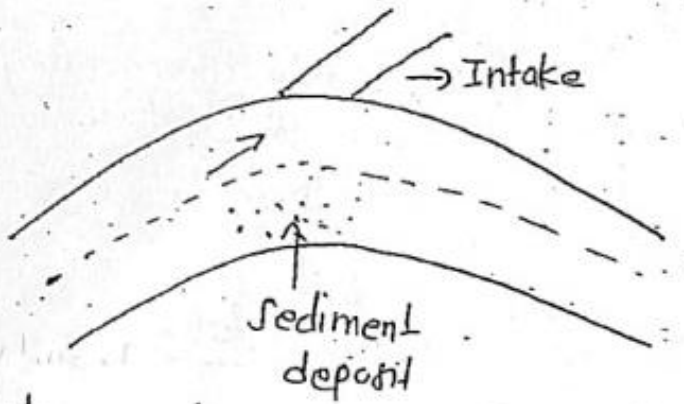
Major Requirements of an intake:

- Adequate inflow
- Less sediment intake
- Less Head loss
- Least environmental impact

→ The location of an intake must be chosen in such a way that it diverts the required quantity of flow with minimum sediment flow into the intake.

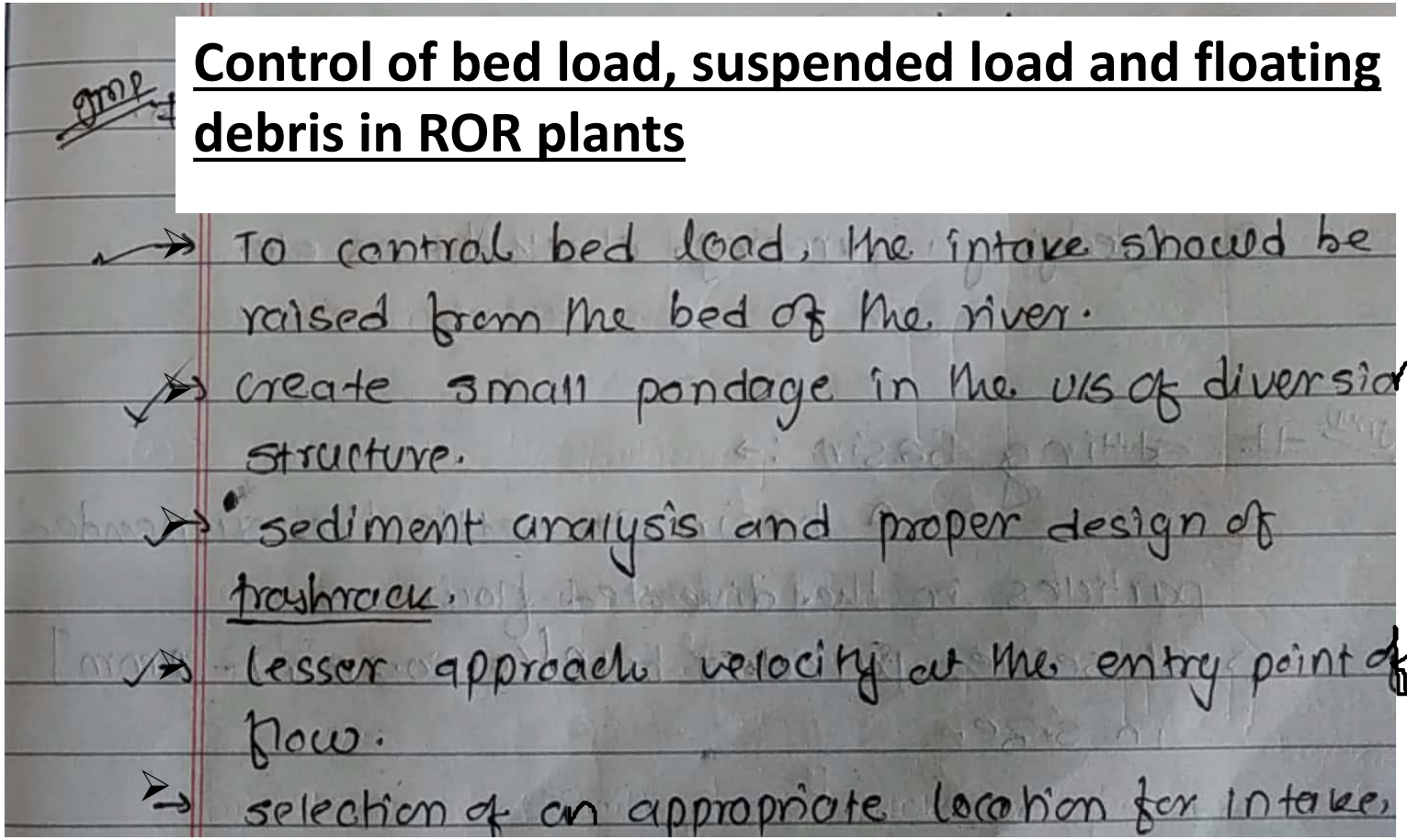
→ The best location for the intake is the outer (concove bank) to avoid bed load.

→ The structure should be aligned to produce a suitable curvature of flow into the intake, and a diversion angle of around 30°-45° is usually recommended to produce curvature of flow.

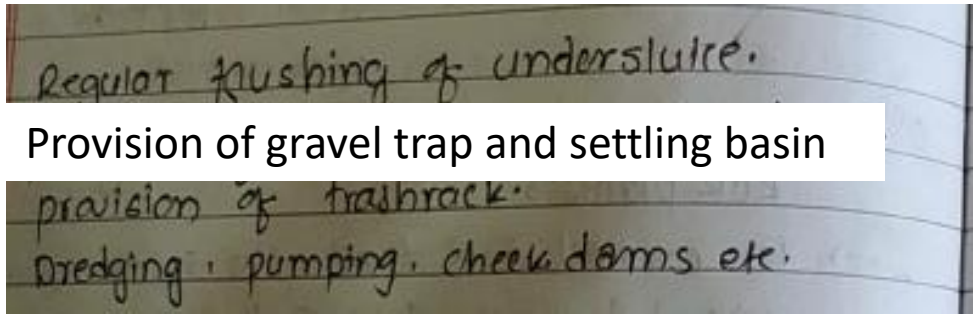


→ The river reach upstream of intake should be well established with stable banks.

Control of bed load, suspended load and floating debris in ROR plants


To control bed load, the intake should be raised from the bed of the river.
create small pondage in the u/s of diversion structure.
sediment analysis and proper design of trashrack.
lesser approach velocity at the entry point of flow.
selection of an appropriate location for intake.

- Provision of Divide wall.



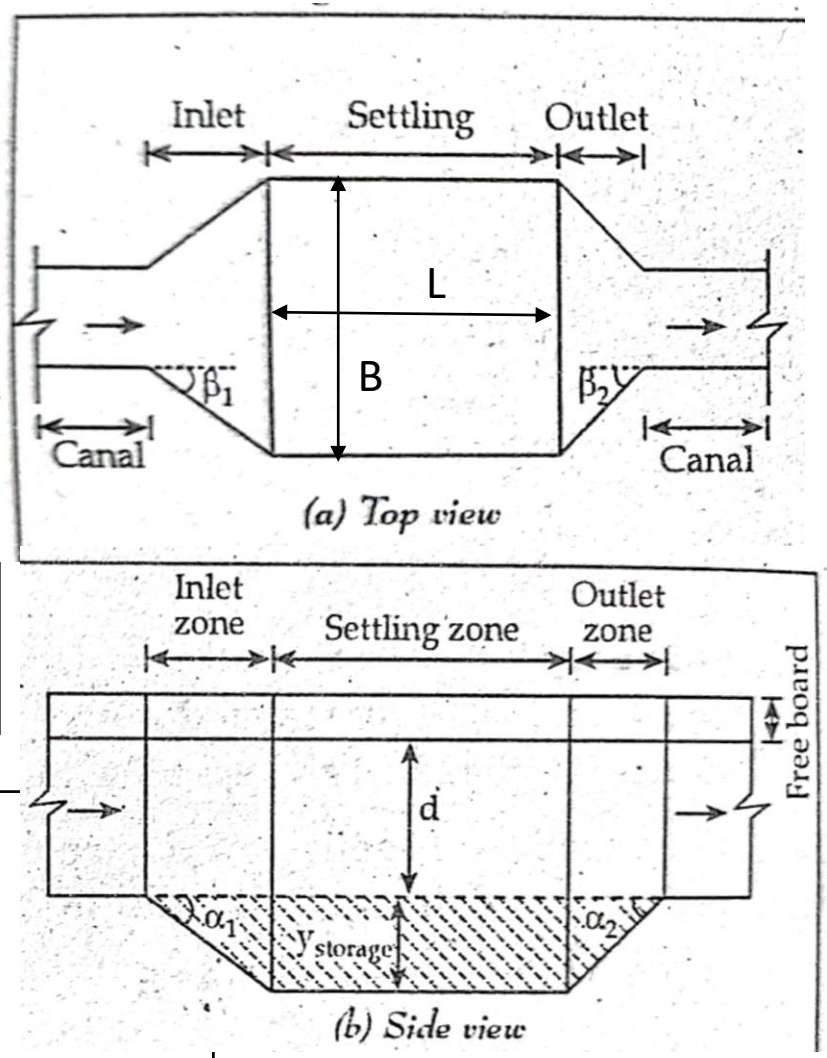
- Provision of gravel trap and settling basin

Settling Basin:

- A basin to settle the suspended particles in the diverted flow.
- It settles particles between (0.1 mm to 2 mm) in size

Zones in Settling Basin:

- Inlet Zone
  - Transition from headrace to settling basin.
  - Horizontal Slope about 1:5 ($\beta_1 = 11^o$) and vertical slope about 1:2 ($\alpha_1 = 27^o$)
- Settling Zone
  - Main part of basin where settling of suspended sediment takes place
  - L/B ratio must be between 4 to 10
- Outlet Zone:
  - Transition zone with gradual narrowing of the width
  - Horizontal slope about 1:2 ($\beta_2 = 26.5^o$), Ver. Slope 1:1



Types (based on Flushing operation):

i. Continuous Flushing Type
   - Flushing is done continuously and does not interfere power production
   - It uses surplus water for flushing, about 10-15% of plant design discharge
   - E.g: Sun Koshi, Adhi Khola, Jhimruk, Modi Khola, Chilime hydropower plants

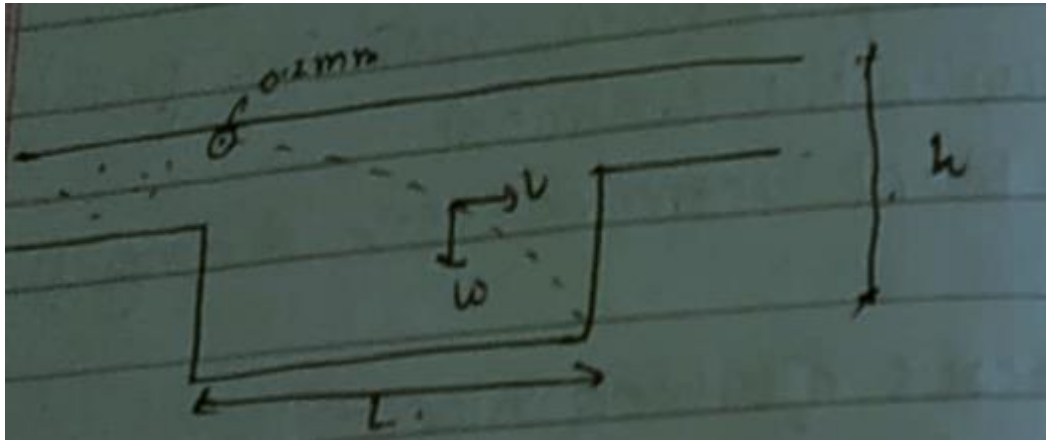
ii. Discontinuous (Periodic or Intermittent) Flushing type
   - The flushing operation is carried out periodically when the desanding basin is full of silt.
   - The power production needs to shut down for single basin design.
   - E.g: Marshyandi, Trishuli, etc.

Design of settling basin

1) Particle approach 2) Concentration Approach

1) Particle approach

The basin is designed in such a way that the time required for settling and travelling horizontal length for a reference particle is just equal.



v = Horizontal Velocity

ω = Fall Velocity

- ω = h/t , v= L/t
- t = h/ ω , t = L/v
- h/ ω = L/v

∴ L = v.h/ **ω**

For numerical,

Assume h, ω is known (or calculated)

L can be obtained.

For v,

$$v = a\sqrt{d}\ ,$$

where d is particle size to be settled (in mm)

v is in m/sec

For Value of a

Diameter of Particle (mm)	Value of a (by T.R. Camp)
> 1 mm	0.36
1mm to 0.1 mm	0.44
< 0.1 mm	0.51

Fall Velocity (ω)

Particle size (mm)	ω (m/s)		
	0 °C	15°C	40 °C
0.05	0.13	0.2	0.3
0.1	0.5	0.7	1.2
0.15	1.0	1.5	2
0.2	---	-----	……

$Q = A * v = B * h * v$

A = Area in cross-section

$\therefore B = Q/(h * v)$

This is the case for no turbulence

<u>Considering Turbulence</u>

New settling velocity (fall velocity)

$= \omega - \omega'$

where, $\omega' = \alpha * v$

v = horizontal velocity

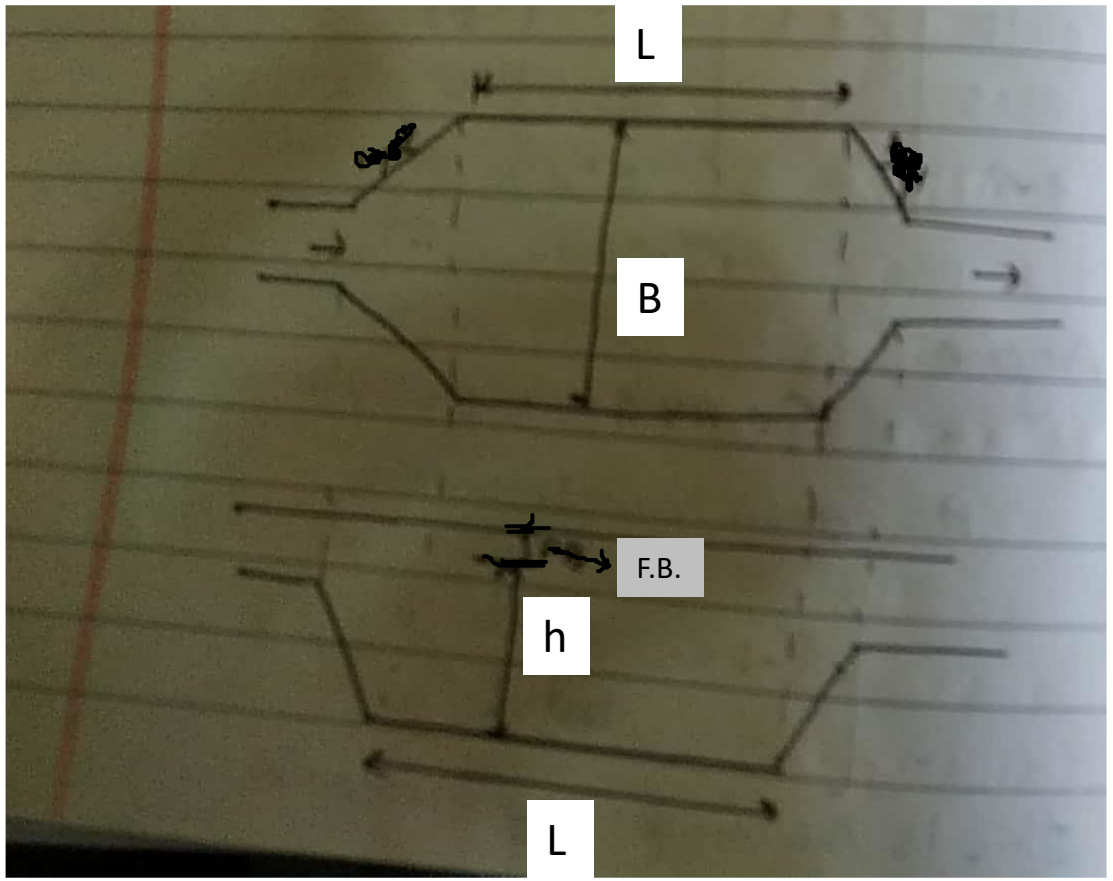
$$\alpha = \frac{0.132}{\sqrt{h}}$$

h = depth in m

Then,

$$\mathbf{L = \frac{v*h}{\omega - \omega'}}$$

$$\mathbf{B = \frac{Q}{h*v}}$$



- Velikonov's formula

Empirical formula for determination of length

$$L = \frac{\lambda^2 * v^2 \left(\sqrt{D} - 0.2\right)^2}{7.51 * w^2}$$

λ = depends upon removal ratio or efficiency.

For 95%, n, $\lambda = 1.2$

For 90%, η, $\lambda = 0.9$

Compute the dimension of settling basin for a hydropower plant using the simple theory with the data given below;
Design discharge = 5 m^3/sec.
Particle diameter to be removed = 0.2 mm
Depth of basin = 3 m
Settling velocity = 2 cm/sec.
If turbulence is considered, what will be dimension of basin?

Solution:

Given that;

$Q = 5\ m^3/sec.$

$d = 0.2\ mm$

$D = 3\ m$

and, $W = 2\ cm/sec. = 0.02\ m/sec.$

The critical flow velocity to be removed particle diameter 0.2 mm is,

$$v = a\sqrt{d}$$

where, $a = 0.44$

$\therefore \quad v = 0.44 \times \sqrt{0.2} = 0.197\ m/sec.$

The length of basin without considering turbulancy is given by,

$$L = \frac{D \times v}{w} = \frac{3 \times 0.197}{0.02} = 29.55\ m$$

And, width of basin (B) $= \frac{Q}{D \times v} = \frac{5}{3 \times 0.197} = 8.46\ m$

Hence, size of settling basin without considering turbulancy is, 29.55 m × 8.46 m × 3 m

Length of settling basin, considering turbulence effect is given as,

$$L = \frac{D \times v}{w - w'}$$

or, $$L = \frac{D \times v}{w - \frac{0.132 \times v}{\sqrt{D}}} = \frac{D \times v}{0.02 - \frac{0.132 \times 0.197}{\sqrt{3}}} = \frac{3 \times 0.197}{4.986 \times 10^{-10}} = 118.53\ m$$

Check for length,

$$L = \frac{\lambda^2 v^2 \left(\sqrt{D} - 0.2\right)^2}{7.51\ w^2}$$

For 95% removal $\lambda = 1.5$;

$\therefore \quad L = \frac{(1.5)^2 \times (0.197)^2 \times \left(\sqrt{3} - 0.2\right)^2}{7.51 \times (0.02)^2} = 68.23\ m < 118.53\ m;$

Hence, ok

Size of settling basin considering turbulence is 118.53 m × 8.46 m × 3 m.

Find settling velocity (ws)

$$W_s = \sqrt{\frac{4}{3} g \cdot \frac{d(S-1)}{C_d}} \quad \text{— (1)}$$

$g = 9.81\ m/s^2$

d = diameter of particle in m

S = specific gravity ($S = 2.65$)

C_d = Drag coefficient.

where,

$C_d = \frac{24}{Re}$, if $d < 0.1\ mm$

$C_d = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$, if $d = 0.1$ to $1\ mm$

$C_d = 0.4$, if $d > 1\ mm$

$Re = \frac{W_s \cdot d}{\nu} \Rightarrow W_s = \frac{Re\ \nu}{d}$ — (ii)

ν = kinematic viscosity.

$\nu = 10^{-6}\ m^2/sec$ at $20^\circ C$

$= 0.9 * 10^{-6}\ m^2/sec$ at $25^\circ C$

1 centistoke = $0.01\ cm^2/sec$.

→ W_s calculated is with theoritical assumption for truly spherical particle for practical considerations, taking 65% of theoretical velocity

W_s (actual) = $0.65 *$ W_s (calculated)

Calculate settling (fall) velocity if $D = 0.2\ mm$, $s = 2.65$ and $T = 25^0C$

Here, $d = 02\ mm$, so it lies transitional zone,

Now, $V_f = \sqrt{\frac{4g(s-1)d}{3xCd}} \ldots\ldots\ldots (i)$

But, $R_e = V_f d/\gamma = \frac{Vfx0.2}{0.9x0.01x10x10} = \frac{0.2V}{0.9}$

$V_f = 4.5Re$

$C_d = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34$

So, equation (i) becomes,

$$4.5Re = \sqrt{\frac{4}{3} x \frac{(9.81x1000)x1.65x0.2}{\frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34}}$$

$$20.25Re^2 = 4316.4/(24/Re + 3/\sqrt{Re} + 0.34)$$

So, equation (i) becomes

$$4.5Re = \sqrt{\frac{(9.81x1000)x1.65x0.2}{\frac{24}{Re}+\frac{3}{\sqrt{Re}}+0.34}} \; x \; \frac{4}{3}$$

$$20.25Re^2 = \frac{4316.4}{\frac{24}{Re}+\frac{3}{\sqrt{Re}}+0.34}$$

$$24Re+3Re^{1.5}+0.34Re^2 = 213.156$$

$$0.34Re^2+3Re^{1.5}+24Re-213.156 = 0$$

Solving, we get, $Re = 6.3$

$$C_d = \frac{24}{Re}+\frac{3}{\sqrt{Re}}+0.34 = 5.34$$

$$So,\ V_f = \sqrt{\left(\frac{4}{3}x\left(\frac{9.81x1000}{5.34}\right)x\ 1.65x0.2\right)} = 28.431\ mm/sec$$

For, actual shape sediment, taking 65% of, $V_f = 18.48$ mm/sec